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SPECTROSCOPY.—*Some remarks on primed terms in the spectra of the lighter elements.*[1] By OTTO LAPORTE, Bureau of Standards. (Communicated by W. F. MEGGERS.)

I. In recent investigations by Heisenberg[2] and by Hund[3] it has been shown that in series spectra of elements with several valence electrons the quantum number which is related to the term character S P D · · · in the following well known way

S P D F G H · · · ·
1 2 3 4 5 6 · · · ·

is not identical with the azimuthal quantum k of the last bound electron, but has to be regarded as a resultant of the moments of momenta of all the valence electrons, obtained by space quantization. In building up a shell of orbits of equal n and k, as pointed out by Pauli,[4] no two electrons may occur which possess the same values[5] of n, k, m_1, m_2 or n, k, m_k, m_r. By applying these principles to a shell consisting of 3_3 and 4_1 electrons, Hund was able to derive all the empirically found terms of the arc spectra of Ca, Sc, Ti etc., from a few low terms of their first spark spectra.

Russell and Saunders,[6] to whom we owe the idea of the quantization of the individual k values, have shown in the case of Ca, that assuming the nineteenth electron to be in a 4_1 orbit gives rise to the ordinary arc spectrum of SPD · · · and spd · · · terms, whereas assum-

[1] Published by permission of the Director of the Bureau of Standards, Department of Commerce.
[2] Zs. f. Phys. **32**: 841. 1925.
[3] Zs. f. Phys. **33**: 345. 1925.
[4] Zs. f. Phys. **31**: 765. 1925.
[5] Compare also S. Goudsmit Zs. f. Phys. **32**: 794. 1925.
[6] Astrophys. Journ. **61**: 38. 1925.

ing it to be in a 3_3 orbit leads to the well known system of primed terms.[7]

II. Recently an interesting (PP′) group of the doublet system has been discovered by A. Fowler[8] in the first spark spectrum of Si (Si II) and by Bowen and Millikan[9] in the arc spectrum of Al and the analogous spark spectra P III, S IV, Cl V and C II, N III, O IV. The low term $^2P_{1,2}$, well known from the series $^2P_{1,2} - n^2S_1$ and $^2P_{1,2} - n^2D_{2,3}$, combines with a very high (in Al I even negative) term $^2P_{1,2}$ whose separations are of the same order of magnitude as that of $^2P_{1,2}$. In their explanation of the (^{2}PP′) group Bowen and Millikan proceed in the following way: If the (Al) atom is in its normal state, two of its electrons are in 3s, one in 3p orbits. We obtain the $^2P'$ state, when one electron is in 3s and two in 3p.

The author cannot agree with such considerations. It is impossible and in contradiction with the general formulation of the alternation law to have several electrons move in the same doublet-energy-diagram and to place several electrons in the same s or p orbit. On the contrary the investigations of Wentzel on double electron jumps and especially the recent successful work of Hund have shown that the arc spectrum has to be built up from the spectrum of the ionized atom; and that all the terms of an *even* arc spectrum (let us say) have to be derived from the *odd* terms of its first spark spectrum. (The same objection holds also for the explanation of the $^3P - {}^3P'$ group of Mg I, Al II etc., as given by Bowen and Millikan.)

In order to understand the explanation given below, it is of importance to know that besides the (^{2}PP′) group numerous other groups exist in the "three electron system" of Si II[10], which apparently involve a double jump: these are the combinations of n^2P and n^2F with a $^2D_{2,3}$ term, which Fowler calls $X_{1,2}$, because it does not belong to any of the established term sequences. In its combinations with $\Delta l = 1$ this term reminds us of the terms $^3P''$ and $^3F''$ of Ca which Russell and Saunders found combining with ^3D. We therefore propose the notation $D''_{2,3}$ for $X_{1,2}$. The explanation of $^2P'$ and $^2D''$ must be given simultaneously, as they are likely

[7] Dr. G. Wentzel kindly informs the author that new data on these terms in Ca, Sr and especially Ba are being published by himself and Dr. Bechert.

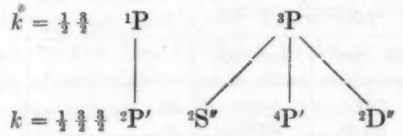
[8] Phil. Trans. Roy. Soc. **A225**: 1. 1925.

[9] Phys. Rev. **26**: 150, 1925; Proc. Nat. Acad. **11**: 329. 1925.

[10] A. Fowler, l. c. 8. In CII, P III, S IV, also an x term has been found, but it seems to be a single level. (Fowler, Proc. Roy. Soc. **105**: 299. 1924; Millikan and Bowen, Phys. Rev. **25**: 600. 1925.) Since the analysis of these spectra is not very complete we must leave it undecided whether these terms correspond to our $^2S''$ or $^2D''$.

to arise from similar configurations. They cannot come from the same term of the preceding spark spectrum, in which case they ought to have almost equal magnitudes like numerous term groups in Ca, Sc, Ti, etc. In Si II the terms in question have the magnitudes: $^2P_2 = 131500$; $^2D''_3 = 76500$; $^2P'_2 = 48050$ cm^{-1}.

A term ^2S, ^2P, ^2D · · · of the ordinary doublet – series system with $l = 1, 2, 3$ · · · belongs obviously to the arrangement $k_1 = 1, k_2 = 1, k_3 = 1, 2, 3,$ · · · · In Hund's notation we may write ^2P $(\frac{1}{2}\ \frac{1}{2}\ \frac{3}{2})$ for the lowest term of Al I, Si II, etc. The only other simple configuration which we may regard as responsible for other terms is $\frac{1}{2}\ \frac{3}{2}\ \frac{3}{2}$ or $k_1 = 1; k_2 = 2; k_3 = 2$. The configuration $\frac{1}{2}\ \frac{3}{2}$ corresponds to a singlet and a triplet P term. We obtain the following terms by adding one more $\frac{3}{2}$ electron and observing Pauli's rule as we have now two equivalent 3_2 electrons.



This is the only reasonable way of obtaining the terms $^2P'$ and $^2D''$. (The terms $^2S''$ and $^4P'$ are not yet found.) As consequences of our scheme are the following combination relations for Si, which, of course, cannot be proved yet on account of the lack of higher series members:

$$\infty\ ^2P - \infty\ ^2D'' = 3^1S - 3^3P = 39330$$
$$\infty\ ^2P - \infty\ ^2P' = 3^1S - 3^1P = 82860$$

We have used total quantum numbers and numerical values for the Si spectrum. It may be noted that $3^3P - 3^3D'' \doteq 55000$ and $3^3P - 3^3P' \doteq 83700$, but we do not wish to attach too much weight to the agreement in the second case. Finally, we call attention to the fact that we have used orbits with total quantum number 3 and 2 (for Boron) only. We therefore have no difficulty in understanding that the frequencies of ($^2PP'$) follow the irregular doublet law in the series Al I, Si II, etc., and B I, C II, etc. We predict the same for the groups ($^2PD''$) also.

III. Since the new development of the theory of series spectra has shown that it is possible to produce terms involving excitation of two electrons in several different ways, one might as well abandon Wentzel's idea that in the $^3P'$ terms of Mg I, Al II etc., the next to the last

electron is in a 3_2 orbit, as it is in the primed terms of Ca, Sr, Ba. We believe it to be in a 3_2 orbit. This gives the following scheme:

$$\begin{array}{cc} \frac{1}{2}\ \frac{3}{2} & {}^1P\ {}^3P \\ \frac{3}{2}\ \frac{3}{2} & {}^1S''\ {}^3P'\ D'', \end{array}$$

^3S, ^1P and ^3D being forbidden according to Pauli's principle.[11] The configuration $\frac{3}{2}\ \frac{3}{2}$ is the only one which gives new terms, as $\frac{3}{2}\ \frac{1}{2}$ is equivalent to $\frac{1}{2}\ \frac{3}{2}$ and a possible configuration $\frac{3}{2}\ \frac{5}{2}$ is not allowed to combine with ^1P $(\frac{1}{2}\ \frac{3}{2})$ and $^3P(\frac{1}{2}\ \frac{3}{2})$ according to Heisenberg's new selection rule. We can now understand why no other primed terms of the triplet system were found in Mg, Be, etc., whereas in Ca, Sr, Ba numerous primed terms are known.

If the suggested configuration is true we have the relation:

$$\begin{aligned} \infty\ {}^3P - \infty\ {}^3P' &= 3^2S - 3^2P \text{ for Mg I, Al II, etc.} \\ &= 2^2S - 2^2P \text{ for Be I, B II, etc.} \end{aligned}$$

We give a few numerical values:

	$3^3P - 3^3P'$	$3^3S - 3^3P$		$2^3P - 2^3P'$	$2^3S - 2^3P$
Mg	36000	35700	Be	37700	32000
Al	56700	54000	B	61500	48400
Si	77000	71700	C	85100	64500
P	97000	89500	N	108300	80000
S	117000	107200	O	131000	
Cl	137000	125000			

The agreement with the above asserted relation is quite satisfactory, although we do not regard it as conclusive proof.

We are led to a much more convincing result by applying Heisenberg's[12] formula for the computation of term separations:

$$\Delta\nu\,(k_1, k_2) = j(j+1)\left\{c\,(k_1)\,\frac{k_1^2 - k_2^2 + l^2 - \frac{1}{4}}{6\,k_1\left(l^2 - \frac{1}{4}\right)} + c\,(k_2)\,\frac{k_2^2 - k_1^2 + l^2 - \frac{1}{4}}{6\,k_2\left(l^2 - \frac{1}{4}\right)}\right\}$$

where k_1 and k_2 represent respectively the two azimuthal quanta of the two electrons, and l is their resultant, the quantum number which defines the term empirically. $c(k_1)$ and $c(k_2)$ are constants which are characteristic for the two electron orbits. In the special case of $k_2 = \frac{1}{2}$ we get, because $l = k_1 = k$:

$$\Delta\nu\,(\tfrac{1}{2}, k) = \tfrac{1}{3}\,j\,(j+1)\frac{c}{k}.$$

[11] It is very probable that a level which coincides with 5D represents the thus predicted $^1D''$ term, because its magnitude is almost equal to that of $^3P'$ (Compare Green and Peterson, Astrophys. Journ. **61**: 301. 1924.)

[12] Zs. f. Phys. **32**: 841. 1925.

But we obtain the same expression by computing the separation of a term whose two electrons have the same azimuthal quanta $k_1 = k_2 = k$; hence:

$$\Delta\nu\ (\tfrac{1}{2}, k) = \Delta\nu\ (k, k).$$

Putting $k = \frac{3}{2}$ we have the result that the ordinary ^3P term in the "two valence-electron-system" ^3P $(\frac{1}{2}\ \frac{3}{2})$ and the primed P term $^3P'$ $(\frac{3}{2}\ \frac{3}{2})$ have the same separations. This agrees fully with the experimental facts. It has been known for a long time, that the $(^3PP')$ groups of Mg I, Al II etc., and Be I, etc., for man almost perfectly symmetrical group of five equidistant lines on account of the equality of the Δ P and Δ P'. The main lines $^3P_1 - {}^3P'_1$, and $^3P_2 - {}^3P'_2$ therefore fall together and can only be separated with spectrographs of high resolving power.[13]

It may be pointed out that this fact, which distinguishes empirically the $(^3PP')$ groups of Mg I, Be I and their analogous spark spectra from the $(^3PP')$ groups of Ca, Sr, Ba, cannot be obtained by assuming the next to the last electron to be in an n_3 or $\frac{5}{2}$ orbit. Another advantage of our viewpoint is, that in using orbits with the same total quantum number (2 for Be, etc., 3 for Mg, etc.) we are able to understand the important discovery of Millikan and Bowen that the $(^3PP')$ groups follow approximately the irregular doublet law.

VOLCANOLOGY.—*Scientific papers and discussions at the 1925 meeting of the Section of Volcanology, American Geophysical Union.*[1]

The fifth Annual Meeting[2] of the Section of Volcanology of the American Geophysical Union was held in the Board Room, National Academy of Sciences, on April 30, 1925. Abstracts of the reports of committees have been published.[3] The following pages contain the original papers or abstracts thereof, together with a report on the discussions, prepared by the Secretary and approved by the speakers.

The report of the Chairman of the Section, presented before the general meeting of the Union, is also included, as it was received from Hawaii too late for publication in Bulletin 53.

ROBERT B. SOSMAN, *Secretary.*

[13] For BeI comp. E. Back, Ann. d. Phys. (4) **70**: 333. 1923; for Mg I: J. B. Green and M. Peterson, Astrophys. Journ. **61**: 301. 1924.

[1] Received Sept. 11, 1925.

[2] This is the second meeting at which a program of scientific papers has been presented. The first of these meetings included the Symposium on Hot Springs held in 1923, the papers having been published in Journal of Geology, **32**: 177–225, 291–310, 373–399, 449–471. 1924.

[3] National Research Council, Bull. **53**: 80. 1925.

Laccoliths and sills. W. M. DAVIS, Harvard University, Cambridge, Massachusetts.

In the Triassic rocks of the Connecticut Valley and New Jersey there occur both overflow sheets such as the Hanging Hills by Meriden and the Watchung Mountains back of Newark, and intrusive sills such as West Rock by New Haven and the Palisades of the Hudson. Both types came into place before monoclinal tilting and faulting occurred. Their composition is practically the same.

The horizontal spread of the sills may be 30 to 50 times their thickness. Laccoliths, on the contrary, usually have a horizontal spread only 5 or 10 times their thickness. The mechanism of the formation of laccoliths is best treated by Gilbert[4] in his description of the Henry Mountains; but there has been no corresponding treatment of the mechanism of sills.

The simplest explanation for the difference between sills and laccoliths is found in a difference in the fluidity of the molten rock, sills being more fluid and laccoliths being viscous; but this explanation will not hold for the laccoliths of the Henry Mountains. It appears necessary to believe that the laccoliths there began with the horizontal penetration of a very thin layer, which was thickened vertically after its horizontal spread was accomplished; for it does not seem possible that horizontal strata could first have been bent and then straightened out again, as would be necessary if the laccolith began as a small dome at the center and spread outward and upward.

Gilbert gave good reasons for believing that a laccolithic intrusion ceases to spread and begins to swell when the lifting force, which increases with the square of the radius of spread, comes to exceed the resistance to flexure in the overlying strata, which increases with the radius. The rate of intrusion may also be a factor. Rapid intrusion may demand a thickening of the intrusion and hence a flexure of the overlying strata when the limiting size of a laccolith is reached, while slow intrusion may give opportunity for a wide-spreading sill of small thickness.

Discussion. H. F. REID suggested that the mechanical relation between the radius and the square of the radius mentioned above would be dependent also upon the rigidity of the strata.

W. CROSS referred to his discussion, published in 1895,[5] showing that the

[4] G. K. Gilbert, *Geology of the Henry Mountains*, U. S. Geogr. Geol. Survey Rocky Mtn. Region, 1877 and 1880.

[5] W. Cross, *The laccolitic mountain groups of Colorado, Utah and Arizona*, U. S. Geol. Survey, Ann. Rep. **14**: 157–241. 1895.

intrusive rock type of the Henry Mountains laccoliths occurs not only in other isolated mountain groups, more or less similar to the Henry Mountains, but also in the structurally complex mountains of Colorado. It occurs throughout the sedimentary section from the base of the Paleozoic to lower Eocene and in all manner of intermediate forms from simplest sill to ideal laccolith, as well as in many unsymmetrical shapes. Further observation since 1895 amply confirms the generalization that while laccoliths closely comparable with Gilbert's ideal one occur mainly in the Cretaceous beds, all other intrusive forms of the same magma may also occur in them.

The mechanical problem of the ideal laccolith of Gilbert is inseparable, geologically, from the broad physical problem presented by the wide range of occurrences of the rock type in question.

Incidentally, Hobbs' hypothesis that the laccoliths of the Plateau Province represent shale fused *in situ* ignores the known facts as to this diversified occurrence.

F. E. WRIGHT mentioned the sills in the Karroo formation of South Africa (Permian to Jurassic). Sills are very numerous but there are no laccoliths. The sills follow the bedding. Dutoit assumes that the underlying strata fall away as the sill spreads. The molten basalt and the shale do not differ much in density. The area as a whole is cut into many blocks. Differential vertical movement is actually shown in outcrops.

Gases in volcanic activity. ARTHUR L. DAY, Geophysical Laboratory, Carnegie Institution of Washington.

In explaining volcanism, data are going to be needed on the following points:

(1) The fluidity of the molten rock when gases are present as contrasted with the loss of fluidity after the gases have escaped.

(2) The state of the material beneath the lava lake of Kilauea during the years preceeding the explosions of May 1924. During these explosions the size of the hole was increased about ten times, but among the debris there is no vitreous material and there is no trace even of contact of the fragments with a liquid. This underlying material has always been concealed by talus. It may have been relatively cold, the lake being fed through narrow tubes extending to greater depths. There has been evidence of lava inlets at no less than three different places. The absence of clearly distinguished tides is perhaps due to the small depth of the lake. Outbreaks of lava at points near each other horizontally but at different levels show that there could not have been hydrostatic equilibrium. These outbreaks may have differed in their points of origin and also in their temperature and pressure. The absence of chemical equilibrium in the gases is consistent with these facts.

Discussion. In reply to questions from E. W. BROWN and W. M. DAVIS as to the density of the lava when full of gas the speaker stated that there were no quantitative data; the density varies from that of a clear liquid containing dissolved gas but no bubbles, over to a light foam consisting mostly of gas bubbles. The gas occurs both in the form of large free bubbles and in the form of bubbly lava masses moving as a unit. The density of the lava when saturated with dissolved gas is probably not very different from its density when free from gas.

In reply to a question from DAVID WHITE, T. A. JAGGAR stated that the geothermal gradient had not been measured in the Hawaiian Islands except in a shallow boring in the Kilauea crater. Down to eighty feet there was no change in temperature and the temperature was lower than in the rocks outside of the crater. The temperature is probably controlled largely by gases and water travelling through the rocks. In reply to a question from PROF. DAVIS, Dr. JAGGAR gave the approximate dimensions of the volcano as follows: diameter of the mountain 60 miles (100 km.), diameter of the crater 3 miles (5 km.); diameter (1925) of the pit about 0.6 mile (1 km.). Sonic soundings show that the slope of the mountain is a continuous curve from above sea-level down to a depth of 16,000 feet (4.9 km.).

Plus and minus volcanicity. T. A. JAGGAR, Hawaiian Volcano Observatory, U. S. Geological Survey.

The explosive eruption of Kilauea in 1924 was dominantly a subsidence and an engulfment of wall rock. There were ejected 28 million cubic feet (0.0008 cubic kilometer) of rock and there were engulfed 7 billion cubic feet (0.21 km.^{3}). This engulfed matter would make an underground fill in the form of an upright cylinder of breccia 3000 feet deep and 1500 feet wide (about 1 $\times$ $\frac{1}{2}$ km.) The fill thus extends below sea-level.

The ratio of ejecta to engulfed matter is 1:253. This ejection-engulfment ratio was here measured for the first time and the maximum enlargement of the pit by engulfment occurred after the maximum of explosion had passed. Collapse and engulfment are common at Kilauea at the end of short lava-flow periods without any explosion. Explosion appears to be pseudo-volcanic, due to meteoric water, and confinement of steam due to lowering of the lava column below ground-water. While the Kilauea engulfments are in progress, the surrounding country tilts inward; the centripetal tilt amounted to 70 seconds at the Observatory in two months, April-June 1924.

These phenomena may be called "minus volcanicity," in contrast to "plus volcanicity" characteristic of rising lava with expulsion of lava gases, centrifugal tilting, overflows, doming of country rock, and rising temperatures where an active solfatara is succeeded by incan-

descence. Both plus and minus classes of volcanic change have been measured at Kilauea. The actual ground levels measurably change.

The normal sequence in a cycle begins with plus movements, the volcano yields, and minus movements then lead to engulfment with or without explosion. Minus volcanicity is dominant in all post-Tertiary volcanism, with down-faulted craters, much explosion, and decadence of external lava activity. Lava activity had reached a maximum in Tertiary time.

It seems probable that lava pressure creates intrusion and a doming strain in the larger crust units, whereas yielding of edifice, effusion, gas collapse with lowering of lava, plugging of craters, inrush of ground-water and steam explosion are features of the topographic units. Engulfment may take place among the larger units where general collapse follows outflow. Thus engulfment may occur in upright chasms amid intrusives such as form long batholiths. It is a question of interest whether such engulfment in deep voids occasions earthquake.

Phenomena of engulfment and consequent "graben" faulting apply to all types of eruption. Rhythmic phenomena, with alternation of magmatic pressure and crustal yielding, may be compounded of a greater or less amount of heating by oxidation of magmatic gas as suggested by Shepherd.

The ratio of active volcanoes to extinct is 1:5. Pseudo-eruption is dominant today. Since 1500 A.D. 72 cubic miles (300 km.^{3}) of explosive matter have been ejected on the Earth and only 12 cubic miles (50 km.^{3}) of lava. By the 1:253 ratio the engulfed matter would equal 18,000 cubic miles (75,000 km.^{3}) for this 425 years; if engulfment for the same period were active amid intrusive magma under the recently "extinct" volcanoes, another 90,000 cubic miles (375,000 km.^{3}) of crustal matter might have been engulfed and assimilated. The visible lava flows of this period, by this reasoning, are as 12 to 108,000 in comparison with the volume of the possible intrusive breccias of the volcanic districts of the world with autogenous heat supply. This takes no account of the Tertiary and earlier volcanic districts of the crust wherein intrusion and engulfment may be seismically and thermally active on a gigantic scale.

Note on the chemical significance of engulfment at Kilauea. E. S. SHEPHERD, Geophysical Laboratory, Carnegie Institution of Washington.[6]

The problem of the energy supply at Kilauea is one of the most puzzling. The temperature of the lava lake has been found to be a scant hundred degrees above the crystallizing temperature of the lava and this temperature is maintained over amazingly long periods. This temperature is that of the hottest lava observed and therefore seems to negative the idea that the heat is maintained by the rise of heated lava from below. It will be remembered that Jaggar's measurements of temperature and depth showed that the highest temperature was just below the lake surface instead of being determined by a continuous rise with depth as had been expected. It is also observed that the places at which the lava is rising steadily are apparently cooler and much quieter than places where the lava is flowing back down carrying the lake crusts with it. These as well as other characteristics of the volcano led Jaggar to his "surface combustion" hypothesis. He deduced that the foundering crusts carried down entrapped oxygen which combining with the volcano gases furnished a part of the necessary heat to maintain the lake temperature. This hypothesis is undoubtedly sound as far as it can reach but the amount of oxygen thus obtainable seems insufficient to furnish the energy required.

It has seemed to us that the problem was essentially a gas problem and for that reason the collection and analysis of the gases from the volcano has been followed up with some vigor. These collections, culminating in the splendid 1919 collection made by Professor Jaggar, have supplied us with all that we may hope to learn from the gases as they reach the surface. If we review the entire series of gases collected from this crater the most striking thing about them is that they are almost completely oxidized. They average about 80 per cent by volume of H_2O with a scant one per cent of components capable of further oxidation. Obviously the gases as they reach the surface are incapable of doing any significant amount of chemical work.

It seems improbable that bubbling steam through the lava could maintain the temperature, no matter how superheated the steam might have been at its source, nor is it readily believed that the necessary amount of gases could be forced lengthwise of the several thousand feet of semi-solid magma column at a sufficient speed, no matter

[6] Read by the Chairman in the absence of the author.

what pressures might be postulated. It is one thing to assume that at a depth of a few thousand feet the solubility of the gas in the magma may reach several thousand liters per kilogram and a different matter to imagine the mechanism whereby such a gas could be moved at relatively high speed up through the solid or pasty column.

There remains the possibility of obtaining heat if the magmatic gases contain a reasonable amount, say five per cent, of combustible gases which can be oxidized in the upper part of the lava column. Here, however, we face the difficulty of applying our reagent, oxygen in some available form, at the proper place and in sufficient quantity. To the writer it seems unnecessarily hazardous to assume that atmospheric oxygen or even water can diffuse through the volcano edifice and *into* the lava column, surrounded as it is by its chilled conduit lining.

It is at this point that Jaggar's recent observation of engulfment comes to our rescue. According to this observation the recession of the lava at the great eruption precipitated something like seven billion cubic feet of ash and oxidized wall rock several thousand feet deep into the heart of the mountain. The ferric iron in this breccia may easily reach five per cent and probably approaches the complete oxidation of the iron present. The new lava froths its way up through this oxidized breccia. On a small scale this mechanism has been frequently observed and such an occurrence was photographed by Day in 1912. It is clear that we have not only a porous breccia which is a good heat insulator but also an ample supply of available oxygen which can react with the oxidizable magmatic gases.

While such calculations are far from precise it can be shown that if the ferric iron of the breccia be only three per cent, which is reduced by the magmatic gases again to ferrous iron, enough heat can be thus obtained to raise nearly two million cubic meters (0.002 km.^{3}) of breccia from 20° to 1200°C. We have not taken into account other sources of heat and it is of course obvious that it is not necessary to remelt the entire breccia. The essential point is that a supply of oxygen sufficient to maintain the lava temperature is thus available.

This explanation has several advantages. It does not require that the upper portion of the lava column be fresh lava continuously brought up from great depths. It avoids the continuous solid—we have too long regarded it as liquid—column through which the gases would be compelled to rise at a rapid rate, and it explains the channels and tunnels in the lake bottom which have been observed at times of sudden draining off of the lake. We conceive the mecha-

nism more or less as follows: the gas-charged magma starts frothing up some crack in the breccia. It fuses out a small and probably tortuous channel for itself taking up oxygen and being heated as it rises. Probably many such channels are formed. When the oxygen supply is exhausted these passages freeze and others are formed. It is not necessary to assume that the breccia is ever completely remelted, in fact the upper portion of it is being constantly renewed during the long periods of quiet activity. At the same time the breccia may be raised or lowered by the forces acting on the main magma in depth in whatever manner seems best. The eccentric currents in the lake find here an easy explanation.

In passing, attention is called to the significance of engulfment in concentrating the rock distillates, that is, the less volatile constituents. For example, sulfur is notably abundant around volcanic vents. This has led some to suppose that the magmatic gases at volcanoes were different in character from magmatic gases in general. Such an assumption is unnecessary. During the prolonged periods of quiet activity this relatively non-volatile element is concentrated in the cooler parts of the breccia and walls. Engulfment continues the working-over and further concentration of this element while the more volatile constituents escape. In a similar way many elements present in minute amounts in the magma become concentrated until with the decadence of the vent there is only enough energy to bring them to the surface and hold them there.

Discussion. F. E. WRIGHT mentioned the kimberlite pipes of South Africa. These consist of brecciated material and contain, at depth, fragments of the Beaufort shale which belongs stratigraphically 2000 feet (0.6 km.) higher and has since been removed by erosion. These pipes have been followed to a depth of 3500 feet (1.1 km.) where they have narrowed down to a size too small to pay for further deepening. Dr. JAGGAR mentioned the throwing out of sedimentary rocks in explosions at Vesuvius.

In reply to questions from H. T. STEARNS and E. T. ALLEN, the speaker stated that the origin of *aa* lava is not yet clear. It may result from a remelting of the breccia. The basaltic magma below carries the gases which rise and by their reactions produce the heat for remelting the breccia. Mauna Iki, the new mountain of 1920, may be of this origin. The *aa* lava, however, contains no visible solid fragments but may contain microscopic, or nearly microscopic, fragments.

L. H. ADAMS mentioned the possible effect of such fragments in causing gas to be released from a super-saturated liquid although it would be held in solution if the liquid were clear and homogeneous.

Gravity and underground lava. F. E. WRIGHT, Geophysical Laboratory, Carnegie Institution of Washington.

One characteristic of volcanoes is the transfer of large quantities of material from one place to another. The methods used in geophysical field surveys may, therefore, be applicable. The problems are, in some respects, similar to those met with in oil exploration. The Eötvös torsion balance is particularly sensitive in showing the variations of gravitational attraction due to inhomogeneities beneath the surface. This method might be applied near a volcano, to find the distribution before and after an explosion. Similarly, methods for detecting changes in the Earth's magnetic field (dip-needle, magnetometer), or in electromagnetic fields produced in the Earth, may be of service; also the seismic methods and possibly the new sonic methods.

Discussion. In reply to remarks by DAVID WHITE and T. A. JAGGAR, the speaker stated that the price asked for the Eötvös balance seems too high; that the photographic apparatus sometimes attached to it is complicated and not necessary in field work. The balance has a sensitivity of 1×10^{-9} dynes per gram. W. D. LAMBERT remarked that the balance measures the gravity gradient so that the effect varies inversely as the cube of the distance; nearby inhomogeneities, therefore, have a large effect.

Tides in lava. E. W. BROWN, Yale University, New Haven, Connecticut.

Solar tides are difficult to distinguish from atmospheric effects. Lunar tides, on the contrary, are distinguishable with certainty by analyses of the records over a number of days. Observations by the staff at Kilauea have been made at intervals of 15 to 20 minutes over a period of 27 days. These indicate tides in the lava crust on the bottom of the pit of Halemaumau with periods of one half and one lunar month and an amplitude of about 3 to 5 cm. but their existence is not certain. On the other hand, the absence of such tides is also not proved. The ocean tides may have an effect through the intermediate distortion of the Earth's crust. A fuller report has been recently published.[7]

Discussion. In reply to questions from A. L. DAY and T. A. JAGGAR, the speaker stated that the Earth's bodily tide would probably not be detectable in the volcano. It does not seem likely that the release of gases could be influenced by the bodily tide.

Dr. JAGGAR suggested that a structure which was long enough in an east and west direction might show some effect. There is a ridge under the

[7] E. W. Brown, Amer. Journ. Sci. **9**: 95–112. 1925.

Pacific 2000 miles or more in length, with Hawaii at one end and it is conceivable that the bodily tides might affect any volcanic phenomenon which depended on movements of this ridge as a unit.

W. D. LAMBERT mentioned that tides had been distinctly observed in certain lignite mines in Bohemia which had been flooded with water. Prof. BROWN suggested that the water levels at the two ends of a pipe leading from the crust in the pit to the outside slope of the mountain would show the effect of the bodily tide. Dr. JAGGAR referred to the use of the horizontal pendulum as a very sensitive instrument for the measurement of tilt, whether due to tides or to the movements of the volcano.

Oxygen and volcanism. ROBERT B. SOSMAN, Geophysical Laboratory, Carnegie Institution of Washington.

Jaggar and Shepherd have called attention to the great importance of oxidation reactions in the activity at Kilauea, but it has been difficult to find a means of supplying oxygen beneath the floor of the crater in amounts sufficient to explain the reactions. The phase rule relationships in the system iron-oxygen and in silicates containing the oxides of iron would allow of a possible supply of oxygen from the deep interior of the Earth.

From researches on the systems Fe: O, Fe: C: O, and Fe: H: O, it appears very probable that the oxide FeO resembles other oxides of the metals of the eighth group of the Periodic System in being stable only at higher temperatures, decomposing as the temperature falls. The decomposition temperature for FeO appears to be between 500 and 600° and occurs according to the following reaction:

$$4FeO = Fe_3O_4 + Fe$$

It is entirely possible, though not yet shown experimentally, that a similar relation may hold, at some temperature, for a given silicate melt containing iron oxides, and that as the temperature falls metallic iron and oxygen may be separated from the liquid. Under ordinary conditions the metallic iron would sink towards the center of the Earth. Under special conditions such as a rapid rush of deep-seated magma, metallic iron might be carried along with the liquid. This would account for the appearance of metallic iron in the basaltic rocks of Greenland and elsewhere.

The oxygen would normally rise toward the surface, producing oxidation reactions at higher levels. This would account for the known occurrence of such reactions at levels below the circulation of meteoric water, such as the formation of sulfates and of martite. The hypothesis would also explain the existence of oxygen in the

atmosphere of the Earth in spite of the fact that its presence there seems at first inconsistent with an originally molten body whose supply of oxygen was so deficient that it now possesses an iron core.

Discussion. DAVID WHITE referred to experiments by S. C. Lind and others on the bombardment of water by alpha particles and its decomposition into hydrogen and oxygen as a possible source of deep-seated oxygen. Dr. SOSMAN replied that if this were the origin of atmospheric oxygen, the quantity of helium in the atmosphere should be larger than it now is, unless it can be shown that the helium, like hydrogen, would be nearly all lost by diffusion into space. T. A. JAGGAR emphasized the view that ferric oxide might be the principal reacting substance in the rocks underlying Kilauea, according to Shepherd's hypotheses, and that neither atmospheric oxygen nor deep-seated oxygen would necessarily have to be called upon directly to account for the deep-seated oxidation of gas described by Shepherd. Keeping up the supply of ferric oxide over long periods of time is still another problem.

Other communications

H. T. STEARNS, of the U. S. Geological Survey, presented some informal notes on the present condition of the volcanoes in Japan, Java and Italy, from observations which he had made on a trip around the World during the months just preceding. In Japan, Oshima and Sakurajima were steaming, Kirishima was in a fumarolic stage, Aso had been recently explosive, Osama was smoking, and Fujiyama was quiet.

In the Philippines, a lake was found in the crater of Taal with no activity visible.

In Java, the volcano Papandajan is about to become eruptive, to judge from the increasing activity of hot springs; liquid sulfur is being shot out 200 feet at a new solfatara and there have been eleven phreatic explosions in the past few months. Galoenggoeng and Tangon Kaprahol are steaming, Bromo has just completed an eruptive cycle. Smeroe shows its usual activity, giving off jets of steam at three-minute intervals. At Merapi, a volcano of the Fujiyama type, the dome of andesite is expanding. At Lamongan, seismic activity indicates that a dome is rising.

In Italy, at Stromboli, there were two boccas, one of which was shooting lava to a height of about 120 feet at intervals of 3 to 15 minutes. The temperature is increasing at Vulcano. Etna and Vesuvius are both in a Strombolian phase.

In closing the meeting, DR. JAGGAR spoke of the possible use of the sonic sounding method, as developed by Hayes, in studying volcano structures. He thought also that some method of direct listening to underground sounds of volcanic origin would yield valuable information, provided that some method of recording these sounds could be developed. It will be necessary first that the rocks involved shall be calibrated with artificial explosions. The use of a

water-well for the transmission of sounds from rock to instrument, the latter being suspended in the water, gives promise of improvements in the record.

Progress of volcanology during 1924.[8] T. A. JAGGAR, Hawaiian Volcano Observatory, U. S. Geological Survey.

During the past year volcanologic services have made progress in Java, Japan, the Philippines, Hawaii and Italy, a new service with a travelling investigator has been established in New Zealand, and a new service has been proposed in Reunion. Provision has been made by the International Union for international libraries at Naples, Catania, and Hawaii. The Hawaiian observatory was transferred July 1, 1924 from the U. S. Weather Bureau to the U. S. Geological Survey. Seismology has been transferred from the Weather Bureau to the U. S. Coast and Geodetic Survey, which will result in placing teleseismic work under the latter. Under the new administrations volcanology thus becomes attached to physical geology in Hawaii, California, Alaska and the Philippines; the Carnegie Institution of Washington investigates macroseismic problems in California; and the Coast and Geodetic Survey cares for those world problems of mathematical seismology which are closely related to gravity and magnetism.

Dr. Friedlaender's *Volcanological Review* (*Zeitschrift für Vulkanologie*) continues to be the best of its kind. The Section of Volcanology of the International Union is now publishing a useful *Bulletin Volcanologique* edited by Dr. Malladra at the University of Naples. A new series of *Annali* of the Royal Vesuvian Observatory is announced. The Hawaiian Volcano Research Association is issuing a weekly *Volcano Letter*. Two splendid monographs have been issued by the Geophysical Laboratory of the Carnegie Institution of Washington, on "Vesuvius" and on "Lassen Peak." The world of volcanology very greatly needs publications on routine activities of the volcanoes of Chile, Iceland, Galapagos, Kamchatka and East Africa.

Some volcanic events of the year have been the explosive eruption of Kilauea in May, 1924, continued upbuilding of the lava floor of the Vesuvian crater, somewhat alarming signs of growing heat and activity in Papandayan, and an eruption on Albemarle Island of the Galapagos group.

[8] Report of the Chairman of the Section of Volcanology to the Sixth Annual Meeting of the American Geophysical Union, May 1, 1925. Previous reports by chairmen of this section have been published as follows: First Annual Meeting, H. S. Washington, Proc. National Acad. Sci. **6**: 583–592. 1920. (Reprint No. 11, National Research Council). Fourth Annual Meeting, A. L. Day, National Res. Council, Bull. **41**: 71–73. 1923.

The Anderson-Wood torsion seismometer promises great usefulness in macroseismic measurement with high magnifications. Optical magnifications of two million have recently been attained in the Wiechert laboratory in Göttingen. The Eötvös balance and electrical sonic ranging both appear applicable to volcanology. Williamson, Adams, Washington, Bowie, Jeffreys, Holmes, and Joly have produced important discussions of the interior of the Earth. Brown has discussed the lava tide at Kilauea. Oxidation, tilt, creep, and changes of elevation are becoming increasingly measurable and demonstrable in relation to underground magma; there are growing new cooperations in volcanological science; and slowly methods of measurement are emerging which promise much for purposes of forecasting, and for setting the observer free from dependence on such discontinuous phenomena as "eruptions."

ENTOMOLOGY.—*A new cactus weevil from Texas.* W. S. FISHER, Bureau of Entomology, U. S. Department of Agriculture. (Communicated by S. A. ROHWER).

The cactus weevil described below was obtained in connection with the prickly-pear insect investigations being conducted by the Commonwealth of Australia at Uvalde, Texas, and was sent for identification by Alan P. Dodd. Mr. Dodd is anxious to have a name for the species to use in papers dealing with cactus insects.

Gerstaeckeria (*Philopuntia*) **doddi,** new species

Black, with the antennae reddish brown; clothed with white, yellowish, and brownish scales. Head with the front sulcate, and densely clothed with white and yellowish scales; beak long, shining, densely punctate, and sometimes longitudinally carinate, in which case the surface is rugosely punctate; eyes rounded above, acute beneath, and separated from each other by two-thirds the width of the beak. Pronotum wider than long, widest at middle, with the sides arcuately rounded and strongly narrowed to apex; surface moderately convex, longitudinally carinate at middle, coarsely, confluently punctate, and sparsely clothed with yellowish and blackish brown scales, with a few whitish ones intermixed. Scutellum invisible. Elytra oval, not wider at base than pronotum, but about one-third wider than pronotum at middle, and without a post-humeral prominence; interspaces wide, and the alternate ones not more densely scaly; strial punctures large, round, rather shallow, and each bearing a large scale; surface rather densely clothed with dark brown and yellow-brown scales, with a few white ones intermixed, the sutural interval more densely clothed with yellowish brown scales, ornamented with a distinct white post-humeral fascia, and a short, irregular, transverse, white fascia just before the apical declivity. Abdomen beneath coarsely, densely punctate, and clothed with whitish scales; second, third, and fourth segments about subequal in length; femora unarmed, and mottled with whitish and yellowish brown scales; claws small and approximate.

Length, 6–7.75 mm.

Type locality.—Uvalde, Texas.

Other localities.—San Diego and New Braunfels, Texas.

Type and *paratypes.*—Cat. No. 28519, U. S. N. M.

Described from eleven specimens; six (one type) collected at the type locality in July, 1924, and August, 1925, by Alan P. Dodd, for whom the species is named; three collected at the same locality, December 11, 1920, and January 30, 1924, by J. C. Hamlin; one from San Diego, Texas, May 7 (Hubbard and Schwarz); and one from New Braunfels, Texas, November 17, 1895 (H. Soltau Collection).

This species belongs to the subgenus *Philopuntia* Pierce,[1] and is closely allied to *porosa* Le Conte and *opuntiae* Pierce. From the former it can be distinguished by the elytra not one-half wider than the pronotum, and from both species by the tarsal claws being approximate, and not widely divergent. It resembles *fasciata* Pierce, from Florida, which also has the tarsal claws approximate, but the elytral markings are different.

The markings on the elytra are fairly constant in this species, but the density of the scales is quite variable. In some specimens the surface of the beak is rather finely punctured and without a longitudinal carina, in others the carina is quite distinct and the surface rugosely punctate.

[1] Proc. U. S. Nat. Mus. **42**: 163. 1889.

SCIENTIFIC NOTES AND NEWS

BRAYTON HOWARD RANSOM, chief of the Zoological Division of the Bureau of Animal Industry and one of the leading parasitologists in the world, died in Washington, D. C., on September 17, 1925, after a brief illness of three weeks.

Dr. Ransom was born in Missouri Valley, Iowa, on March 24, 1879. He was graduated from the University of Nebraska with the B.S. degree in 1899, with the M.S. degree in 1900, and with the Ph.D. degree in 1908. He came to Washington in 1902 as assistant in zoology in the Hygienic Laboratory of the U. S. Public Health and Marine Hospital Service, and in 1903 he was transferred to the Bureau of Animal Industry as assistant in charge of the zoological laboratory in which capacity he served until 1906 when he was raised to the rank of Chief of the Zoological Division. Under Dr. Ransom's leadership the Zoological Division developed to great importance in the organization of the Bureau of Animal Industry contributing to the solution of many important practical and purely scientific problems pertaining to parasitology and related subjects and thereby achieving a world wide reputation. In the solution of these problems Dr. Ransom played the most conspicuous rôle, his own researches in parasitology constituting an enviable record of scientific accomplishment.

In recognition of his work Dr. Ransom had many honors bestowed on him. He was a member of the following scientific societies: The American Microscopical Society (President), The American Society of Naturalists, The American Society of Zoologists, The American Association for the Advancement of Science (Fellow), The American Society of Tropical Medicine (Secretary-Treasurer), The American Veterinary Medical Association (Honorary Member), The Biological Society of Washington, The Helminthological

Society of Washington (Past President), The Washington Academy of Sciences (Vice-President), The American Society of Parasitologists (Councillor), the Société Pathologie Exotique (Foreign Correspondent) the Reale Academia d'Agricoltura di Torino (Foreign Correspondent). He was honorary Assistant Custodian of the Helminthological collections of the U. S. National Museum, and a member of the editorial boards of the Journal of Parasitology and the American Journal of Tropical Medicine. He was a U. S. delegate to the Seventh International Zoological Congress, a delegate to the Fourth Fisheries Congress, and a delegate to the First Pan-American Scientific Congress. He was a recipient of the gold medal of the Seaman's Tropical Disease Research Association of Kobe, Japan, in recognition of his contributions to the life history of Ascaris.

His scientific contributions involve numerous publications dealing largely with the morphology, taxonomy, and life history of parasitic worms and with the practical application of facts ascertained by himself and by others to the prevention of parasitic diseases in man and in domestic animals. Richly endowed with a healthy scienific curiosity, with resourcefulness, thoroughness, and the ability to apply himself unswervingly to the solution of baffling problems, he brought these qualities to bear on his work, his writings being thoughtful, finished, and scholarly productions. His many charming personal qualities, his unassuming dignity, his thoughtful consideration for the feelings of others, his high sense of justice, and his frankness are reflected in his scientific papers which are singularly free from personal criticism, from unwarranted conclusions and are liberal in acknowledging the contributions of other scientific workers. It is a great tribute to Dr. Ransom's scientific achievement that despite his extensive and highly important contributions to parasitology and medical zoology covering a quarter of a century none of his major scientific work has ever been challenged.

Dr. J. N. Rose, associate curator of the Division of Plants, National Museum, has received the degree of LL.D. from Wabash College.

Dr. John M. Coulter, head of the botany department of Chicago University since 1896, has joined the resident staff of the Boyce Thompson Institute for Plant Research at Yonkers, New York.